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ABSTRACT

Path analysis was used to reanalyze Kropp and Stoker's data from tests designed to evaluate Bloom's taxonomy of educational objectives in the cognitive domain. Scores for 1,128 students in grades nine through twelve were analyzed separately by grade level for four content areas on six taxonomic levels. A measure of general ability was also included in the 16 correlation matrices. Two different path analysis procedures were used, one depending on squared semipartial correlations and the other depending on standardized partial regression coefficients. In addition, each matrix was factor analyzed by image analysis procedures. The two different path analysis methods differed in their interpretation of whether prior intelligence or prior knowledge made a greater contribution toward comprehension. The results generally supported the hierarchical nature of the taxonomic tests, with the exception that evaluation appears to be more an effect of comprehension than of synthesis. The factor structures for grades nine and twelve were highly similar. (CTM)

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Establishing a Causal Model for Bloom's Taxonomy through Path Analysis

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Establishing a Casual Model for Bloom's Taxonomy through Path Analysis

One of the most widely used classification schemes for specifying and evaluating cognitive outcomes of instruction has been the Taxonomy of Objectives, Handbook I: Cognitive Domain (Bloom, Engelhart, Furst, Hill & Drathwohl, 1956). Originally set forth as the result of a logical analysis, the Taxonomy is comprised of six levels: Knowledge, Comprehension, Application, Analysis, Synthesis, Evaluation -- which are arranged in a cumulative hierarchy. Thus, comprehension depends upon prior mastery of knowledge or facts, application depends upon comprehension of relevant ideas or concepts, which in turn is built upon mastery of relevant knowledge, and so on. Implicit in the Taxonomy is the notion that instructional outcomes move from simple to complex, concrete to abstract.

One of the earliest and most comprehensive attempts to provide empirical data bearing on the construct validity of the Taxonomy was undertaken by Kropp and Stoker (1966). Four tests were constructed for use with students in grades nine through twelve from reading passages entitled Lisbon Earthquake, Stages of Economic Growth, Atomic Structure, and Glaciers. The first two dealt with social science content, the latter two with natural science content. Each test consisted of six subtests corresponding to the major levels of Bloom's taxonomy.

On the basis of mean levels of performance and simplex analysis, Kropp and Stoker (1966) felt "there was a clear tendency for the empirical data to support the imputed hierarchical structure of the Taxonomy." Another objective of their study was to gather evidence which would support or refute the claim by Bloom et al. (1956) that the cognitive processes specified by the Taxonomy were content free. This hypothesis was evaluated by factor analysis. Kropp and Stoker reported that "the usefulness of the factor analysis results were seriously impaired because unrotated factor factor matrices had to be interpreted and the majority of the factors which were extracted were mixtures of content and process. The presence of these mixed factors tends to discredit the hypothesis and to suggest the scores are determined by highly complex interactions of content and process."

More recently, Madaus, Woods, and Nuttall (1973) conducted a reanalysis of Kropp and Stoker's data with two objectives in mind. The first was to construct a quantitative causal model to further explore the validity of the cumulative hierarchical structure of the Taxonomy. A second objective was to determine the effect of introducing a "g" factor (general intellectual ability) into the causal flow of the taxonomic structure. The latter analysis was made possible since Kropp and Stoker (1966) had administered 37 tests from the Kit of Reference Tests (Kit) for Cognitive Factors (French, Ekstron & Price, 1963). The Causal model constructed by Madaus et al. (1973) was intended "to reveal not only proportion of variance in each level explained directly by the preceding adjacent level, but also any proportion of variance in each level explained directly by the preceding adjacent level, but also any proportion of variance explained indirectly by nonadjacent levels."

The results of the Madaus et al. (1973) reanalysis revealed only one strong indirect link, Comprehension to Analysis. However, the addition of a "g" factor into the causal flow "revealed that the direct links between the adjacent lower levels from Knowledge to Analysis decreased considerably in magnitude and that the direct links between the adjacent higher levels from Analysis to Evaluation became too weak in general to be retained in the model." The result was a Y-shaped structure with Comprehension leading to to Application on the one hand and Analysis on the other.

The present reanalysis of the Kropp and Stoker (1966) data was undertaken mainly in reaction to the Madaus et al. (1973) methodology and to further investigate certain aspects of their findings. Further investigation of Kropp and Stoker's (1966) inability to separate content from process was deemed worthwhile through an analysis of rotated factor matrices.

Madaus et al. (1973) chose to use commonality analysis (Kerlinger & Pedhazur, 1973) as the method for determining link coefficients in their causal model. This procedure essentially calculates the semipartial correlation between two variables. Moreover, "g" was partialled out of each taxonomic measure when determining the linkage between one level and another. It may be argued that it is questionable to partial out an exogenous variable of a potentially multivariate nature (see Kropp & Stoker, 1966, pp. 114-117) from all endogenous variables in a causal flow model.

An alternative path analysis as developed by Wright (1934) was employed in the present investigation. Two models were used: one in which "g" was considered as the exogenous variable causing Knowledge and one in which Knowledge was considered exogenous causing Intelligence. This second model

was based on Cattell's (1971) distinction between fluid (gf) and crystallized (gc) intelligence. The KIT tests likely contain substantial gc, a factor consisting primarily of acquired skills and knowledge. Recent evidence supports the hypothesis that achievement can be causally prior to intelligence (Crano, Kenny & Campbell, 1972; Dyer & Miller, 1974).

Lastly, Madaus et al. (1973) reported a summary causal model by collapsing the data across the four content areas and four grade levels. However, they also discuss a trend of change across grade levels in the relationship of "g" to taxonomic subtest performance and content. For grades nine and ten with natural science passages, the Synthesis and Evaluation subtests appeared to be more dependent upon "g" than mastery of the preceding levels of the Taxonomy. But for grades eleven and twelve, the direct links between Analysis, Synthesis and Evaluation were strong enough to be retained in the model. It was hypothesized that the younger subjects had not yet developed the "common sense" of the eleventh and twelfth graders and were more dependent upon "g" as a result. Since the Taxonomy ostensibly moves from concrete to abstract in terms of the cognitive processes that are required, a developmental shift from concrete to formal operational thinking, in Piagetian terminology, may be hypothesized. The observation of such shifts, as observed by Madaus et al. (1973) mitigates against considering content and grade specific samples as "replications" for path analysis. Rather, it would appear more appropriate to obtain path coefficients for grade and content levels independently.

Method

Subjects

Records were obtained from the original Kropp and Stoker (1966) data

on 1,128 students in grades nine through twelve containing scores on six taxonomic type tests from each of the four content areas outlined earlier and a general ability factor score from the Kit Tests. Students in the original sample were enrolled in ten Florida schools. Further description of the sample, the tests, and test administration are reported by Kropp and Stoker (1966).

Procedures

Path analyses were completed on the 16 correlation matrices representing the four grades and four content areas. Each matrix consisted of the general ability factor (g) and the six taxonomic subtests: Knowledge (K), Comprehension (C), Application (A), Analysis (N), Synthesis (S), and Evaluation (E). This paper will deal primarily with the matrix obtained for Atomic Knowledge across the four grades. Also, an average taxonomic subtest score was calculated for each subject and correlations, including the "g" score, were determined for subjects across grade levels.

Two path analysis procedures were utilized. The first involved procedures employed by Madaus et al. (1973). In this method, direct links among the taxonomic level subtests are obtained as squared semipartial correlations with "g" partialled out of the causing prior level subtest. This is comparable to commonality analysis (Kerlinger & Pedhazur, 1973), which determines unique variance components of a criterion variable. Indirect links were estimated by the squared semi-partial correlation of a level with a nonadjacent level, partialling the preceding direct level. For example, the indirect link of Knowledge to Evaluation would be obtained by the squared semi-partial correlation of Evaluation with Knowledge partialling synthesis ($R^2E:S,K - R^2E:S$). It should be noted that such estimates of indirect links will also reflect common variance with other indirect causing variables since they are not

partialled out. Only the directly preceding variable is partialled.

The second procedure utilizes the standardized partial regression coefficients obtained by the regression of each level on all preceding levels.

The two methods selected may be contrasted in their interpretation. For the first, the variance of a level is analyzed into unique and common variance components. For the second method, the correlation between any two variables is the sum of direct path coefficients plus the product of path coefficients for indirect effects. Madaus et al. (1973) did not report all unique and common variance components for each level. Their analysis contrasts the important links by comparing the coefficients obtained when "g" is present to when it is not present. In addition, they use the mean coefficients of the 16 sets of grade by content matrices rather than coefficients obtained on correlations among average content scores across grades.

Complete path analyses were performed by the second method described above. Partial analyses were performed by the first method only for the direct links among levels and links to "g" for comparison with those obtained by the second method.

In addition to path analyses, each matrix was factor analyzed by Image Analysis procedures and the resulting matrix rotated by the varimax method. Only factors with eigenvalues of 1.0 or greater were rotated. If general ability is a primary cause of performance on the taxonomic tests, then a single "g" factor should explain a high percentage of the matrix generalized variance and commonality values should be high. If, on the other hand, each taxonomic level test contributes considerable unique variance, commonalities should be low and common factors should explain smaller portions of matrix variance.

Madaus et al. (1973) report finding a grade by content interaction, although the method was not described. If performed by a two-way analysis of variance with repeated measures, the results would reflect variation among sample means. Since it is reasonable to expect differences among grade means, content means, and grade-content cell mean interactions, it is also reasonable to expect some grade, content, and grade-content variation in the intercorrelations of the taxonomic scales. Methods for analyzing correlation matrices for combined within-subject and between-subject designs with variance components due to differences among means removed, are not developed. The investigators therefore relied upon descriptive techniques involving transformation of the correlation matrices by principle components and comparison of the resulting pattern matrices (Veldman, 1967, Program "Relate", p. 238). Factor comparisons were completed for each content test, comparing in each case the ninth grade matrix with the twelfth grade matrix.

Results

Figures 1-4 present the correlation matrices and path coefficients obtained by the semi-partial correlation and standardized regression methods for Atomic Knowledge (others available on request). Figure 5 presents the correlation matrix and path coefficients for the two methods for Atomic Knowledge when all grades are combined. Two conclusions may be drawn: (1) Standardized regression coefficients used to estimate path coefficients result in an interpretation which reduces the importance of general ability as a variable causing performance in subsequent taxonomic level tests while use of squared semi-partial correlations as path coefficients leads to implications that general ability is a more important cause. (2) Collapsing subjects across the four grades masks potentially important variation in path structures among grades. In particular, use of the average semi-partial correlation obtained across groups yields different coefficients and conclu-

sions than when coefficients are obtained directly on the combined observations. Thus, the method of using average squared semi-partials, as in the Madaus, et al. (1973) study, is questionable.

Figure 6 presents the path structure obtained by first calculating an average taxonomic subtest score across the four content areas for each subject and computing the intercorrelation among these averages for subjects across all grades. Figure 7 presents the original correlation matrix underlying Figure 6 and the comparison of coefficients by the two methods. In general, Figure 6 substantiates the hierarchical nature of the taxonomic tests, with the exception that Evaluation appears to be more an effect of Comprehension than Synthesis. The "Y" shaped branch obtained by Madaus et al. (1973) from Application to Synthesis did not appear plausible. Moreover, the contribution of "g" is substantially attenuated in this analysis. It should also be noted that if Knowledge is considered to be the exogenous variable causing "g" with "g" subsequently causing Comprehension, then the symbols of "g" and "C" only need be reversed. The figure would then indicate Knowledge as an important cause of both "g" and Comprehension, with "g" a relatively weak cause of Comprehension. This model appears particularly viable in light of the preceding discussion on the nature of the KIT test and its sensitivity to cultural knowledge acquisition.

Figure 8 presents the varimax rotated principle factors for grades 9 and 12 on the taxonomic subjects of Atomic Knowledge. In this figure, 12th grade loadings have been rotated for maximum congruence to 9th grade loadings. Cosines of angles between corresponding subtest vectors are also presented. It is apparent that the structure of these two matrices are highly similar.

Discussion

Alternative Methods

Path analysis is based on assumptions of causal flow models. A question addressed in this presentation is which index, a semi-partial correlation coefficient or a standardized partial regression coefficient, yields results more congruent with the assumptions. The semi-partial coefficient contributes information concerning the unique contributions of variables to the variance of another. The standardized partial regression coefficient provides information concerning the relative contribution of variables. Using the data of this research, it may be asked, "Is it more reasonable to attribute achievement of Comprehension scores primarily to prior attainment of intelligence or prior attainment of Knowledge?" An experimental approach to the question might be to examine the linear relationship of intelligence to Comprehension while holding Knowledge constant among subjects. Alternatively, the relationship between Knowledge and Comprehension could be assessed using subjects with equal intelligence. If the linear relationship in the second situation were greater than in the first, it would be logical to infer that prior knowledge is a more important causal variable than intelligence. Since few opportunities exist to select subjects matched on either intelligence or knowledge, the use of partial correlation procedures are usually adopted. If one examines Figure 2, for example, and accepts the argument just given, then the coefficients obtained indicate that prior knowledge is, indeed, a greater contributor to Comprehension than intelligence. That is not the conclusion one would arrive at, however, if semi-partial correlations were used.

General Intelligence or Knowledge as the Exogenous Variable

Nature-nurture views provide alternative models of causation. In a

directional flow model without "feedback" loops, one is perhaps forced to assume either that knowledge acquisition flows from the prior disposition to learn as measured by an intelligence test, or that performance on an intelligence test flows from prior acquisition of knowledge. The choice of tests to measure intelligence is, therefore, a critical factor in choosing which is the prior variable. It is argued here that the use of the KIT tests as the measure of intelligence leads to use of knowledge as the prior (exogenous) variable. The previous cited literature on the KIT test suggests that the scores obtained are influenced by learning experiences of the individual tested. Using knowledge as the exogenous variable does imply a "knowledge" greater than that sampled by the taxonomic subtests for knowledge, just as intelligence would consist of more than that measured by the KIT test.

The interchange of the positions of Knowledge and intelligence in the path analysis does not alter the standardized regression coefficients obtained. It does, however, alter the interpretation, that is, Knowledge has a considerably larger influence on subsequent taxonomic level achievement than does general ability. This finding would hold for either method of obtaining path coefficients.

Effects of Combining Content-Specific and Grade-Specific Data

A cursory examination of Figures 1-4 illustrates the considerable variation in path structures resulting from analyses across different grades, even within the same content area. Combining the repeated measures within grades for taxonomic subtests and combining grade samples also yields a different structure than obtained for separate grades (e.g., compare Figures 5 and 6). While the pattern of intercorrelations among taxonomic subtests

were found to be highly similar through comparison of the factor structures obtained for different grade and content matrices, variation in score means from grade to grade and content test to content test are different. In particular, serious "floor" effects appear to be operating in the measures of Synthesis and Evaluation subtests as evidenced by standard deviations which exceed the means of those subtests. Factor analysis of all subtests in a grade (4 content areas times 6 taxonomic subscales) suggest strong content-specific factors, while factor analysis of individual content taxonomic subtests results in subtest-unique factors. These analyses strongly suggest, therefore, the presence of both content and subtest factors. Combining content (and grades) to complete path analyses would, therefore, be expected to mask important taxonomic structure variations. This problem appears to be further exacerbated through the practice of using average squared semi-partial correlations as was done in the Madaus et al. (1973) study.

The findings of this study suggest that Bloom's Taxonomic Model may have less validity when applied to specific content and grade combinations than when applied to aggregate data. The results also suggest that, unlike the Madaus findings, evaluation skills are more directly influenced by Knowledge and Comprehension than be Synthesis skills (see Figure 6). This finding must be tempered, however, by the "floor" effects apparently operating in the measurement of evaluative skills.

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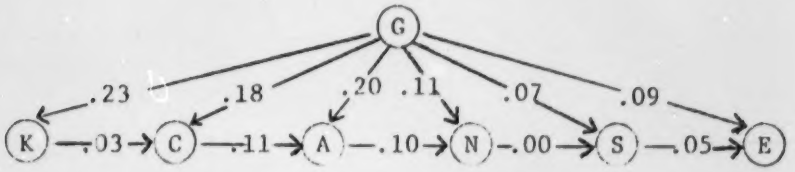
Figure 1 - 9th Grade Atomic Knowledge (N=248)

CORRELATION MATRIX

Variable	G	K	C	A	N	S	E
G	1	.48400	.42559	.44264	.33636	.27084	.29507
K		1	.36553	.35621	.08990	.24117	.30852
C			1	.48968	.46953	.20425	.23154
A				1	.43342	.24648	.32462
N					1	.09820	.11641
S						1	.28914
E							1

RESULTS BY SEMI-PARTIAL CORRELATIONS



RESULTS USING STANDARDIZED REGRESSION WEIGHTS

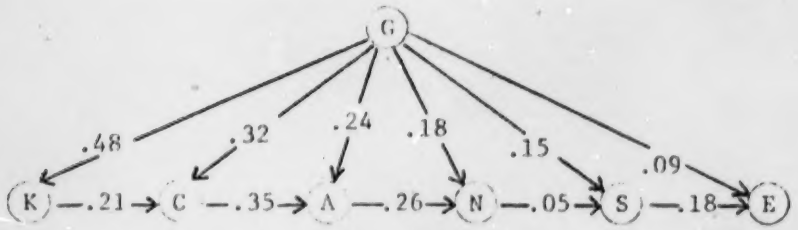
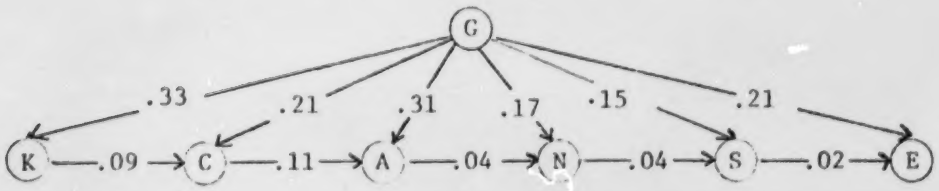


Figure 2 - 10th Grade Atomic Knowledge (N=219)

CORRELATION MATRIX

Variable	G	K	C	A	N	S	E
G	1	.57566	.45287	.55325	.41490	.38973	.45591
K		1	.50462	.48614	.35443	.34692	.42774
C			1	.55208	.51226	.27810	.19436
A				1	.40599	.31296	.29989
N					1	.34460	.30625
S						1	.32228
E							1

PATH ANALYSIS USING SEMI-PARTIAL CORRELATIONS



PATH ANALYSIS USING STANDARDIZED REGRESSION COEFFICIENTS

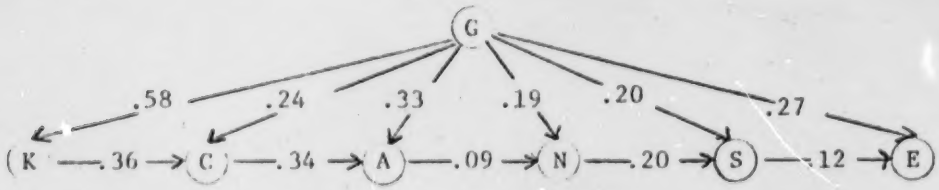
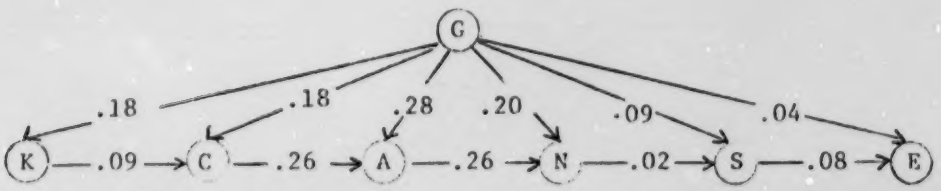


Figure 3 - 11th Grade Atomic Knowledge (N=206)

CORRELATION MATRIX

Variable	G	K	C	A	N	S	E
G	1	.42496	.42261	.52718	.44821	.30174	.20717
K		1	.44873	.43781	.32129	.29948	.32110
C			1	.68219	.60023	.30539	.21379
A				1	.66791	.24270	.17170
N					1	.27031	.15901
S						1	.33362
E							1

PATH ANALYSIS USING SEMI-PARTIAL CORRELATIONS



PATH ANALYSIS USING STANDARDIZED REGRESSION COEFFICIENTS

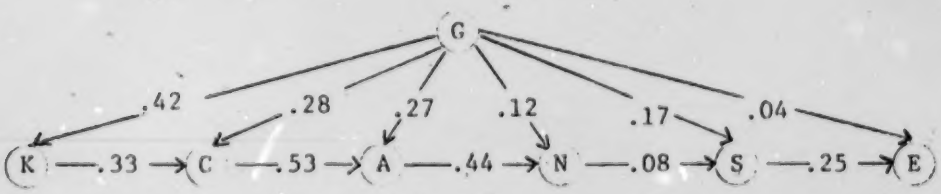
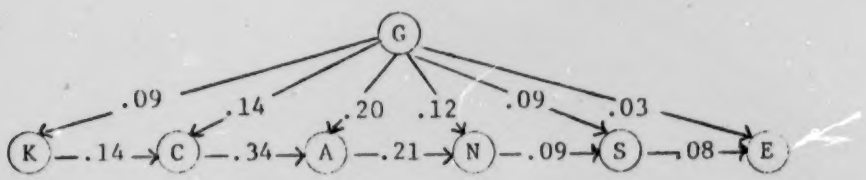


Figure 4 - 12th Grade Atomic Knowledge (N=209)

CORRELATION MATRIX

Variable	G	K	C	A	N	S	E
G	1	.30353	.37290	.44508	.34945	.29554	.16791
K		1	.37555	.39889	.16730	.33903	.26975
C			1	.58518	.50896	.32436	.28255
A				1	.45810	.34801	.21883
N					1	.29727	.12910
S						1	.28045
E							1

PATH COEFFICIENTS USING SEMI-PARTIAL CORRELATIONS



PATH COEFFICIENTS USING BETA WEIGHTS

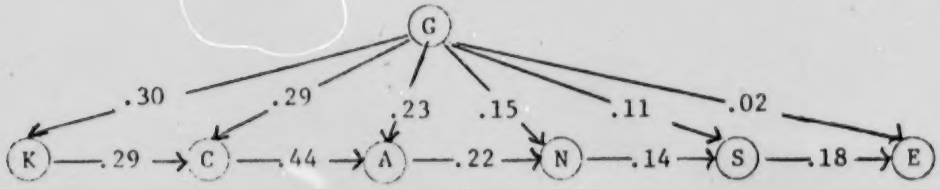
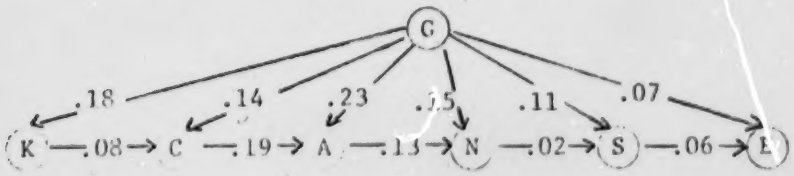


Figure 5 - Combined Grades Atomic Knowledge (N=882)

CORRELATION MATRIX

Variable	G	K	C	A	N	S	E
G	1	.42547	.37921	.47708	.38797	.33039	.26880
K		1	.41976	.41579	.23381	.29568	.32241
C			1	.58068	.51941	.27522	.23076
A				1	.50527	.28997	.25315
N					1	.25990	.18097
S						1	.31204
E							1

PATH ANALYSIS USING SEMI-PARTIAL CORRELATIONS



PATH ANALYSIS USING STANDARDIZED REGRESSION COEFFICIENTS

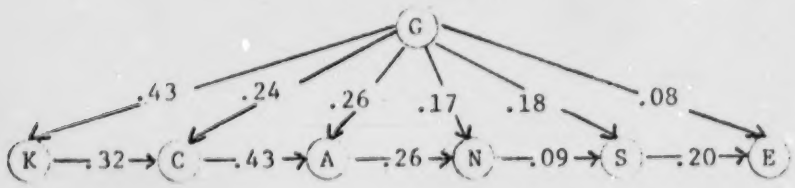
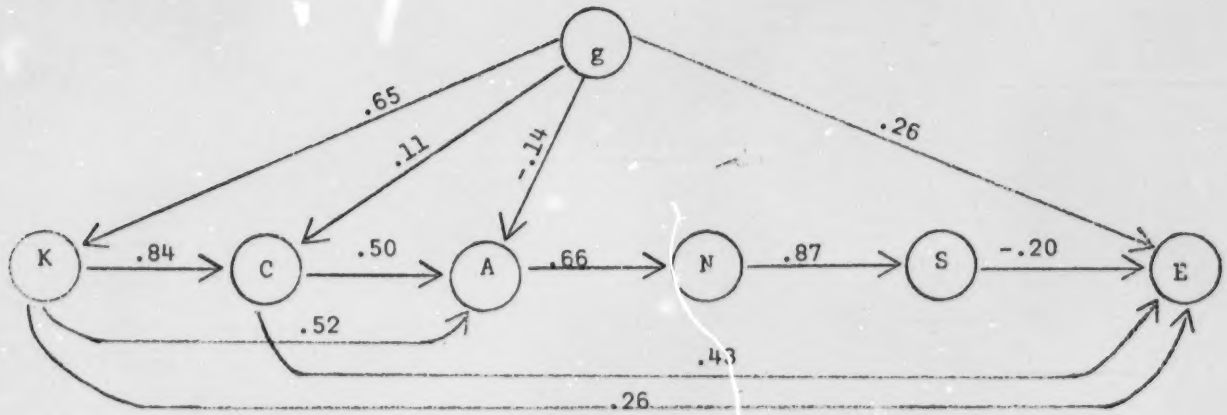


Figure 6 - Path Coefficients for Taxonomic Subtest Averages for Combined Grades (N=1,128)*



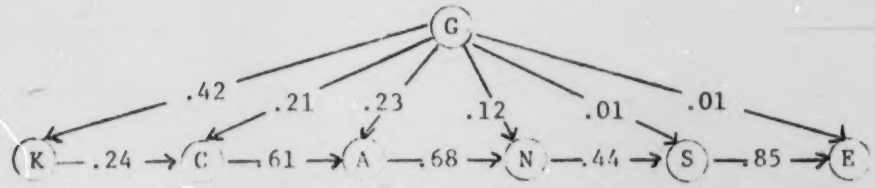
* Paths with coefficients <.08 (absolute value) not shown

Figure 7 - Combined Content Analysis across All Grades (N=1127)

CORRELATION MATRIX

Variable	G	K	C	A	N	S	E
G	1	.64940	.65778	.52994	.31198	.33552	.50079
K		1	.91309	.88980	.57490	.57832	.45756
C			1	.88731	.57234	.57474	.47590
A				1	.65187	.65080	.34043
N					1	.92545	.08097
S						1	.07771
E							1

PATH ANALYSIS USING SEMI-PARTIAL CORRELATION COEFFICIENTS



PATH ANALYSIS USING STANDARDIZED REGRESSION COEFFICIENTS

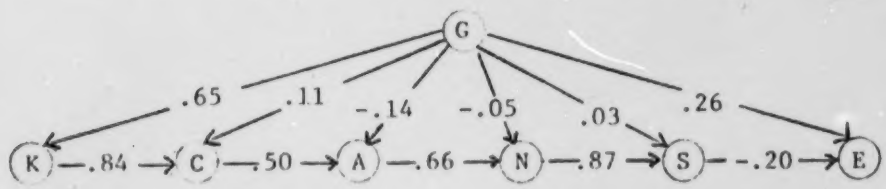


Figure 8 - Ninth and Twelfth Grade Atomic Knowledge Subtest

Principle Components Rotated to Maximum Congruence

		Orthogonal Component							
Variable	Grade	I	II	III	IV	V	VI	VII	Cosines
General Ability	9	.15	.11	-.24	-.12	-.18	.16	-.92	
	12	.15	.10	-.13	-.10	-.18	.12	-.95	.993
Knowledge	9	-.01	.10	-.94	-.13	-.13	.15	-.21	
	12	.02	.15	-.96	-.05	-.15	.15	-.12	.994
Comprehension	9	.23	.08	-.16	-.08	-.20	.92	-.17	
	12	.24	.11	-.16	-.02	-.26	.90	-.16	.996
Application	9	.20	.10	-.15	-.14	-.92	.21	-.17	
	12	.19	.13	-.18	-.11	-.90	.26	-.19	.997
Analysis	9	.95	.02	-.01	-.03	-.19	.21	-.13	
	12	.94	.11	-.05	-.05	-.19	.22	-.14	.997
Snythesis	9	.03	.98	-.09	-.12	-.08	.07	-.10	
	12	.12	.96	-.15	-.05	-.13	.12	-.12	.990
Evaluation	9	.03	.14	-.13	.97	-.12	.08	-.10	
	12	.05	.23	-.22	.89	-.19	.17	-.15	.976